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A Blockchain based Framework for Secure Data Offloading in Tactile Internet Environment

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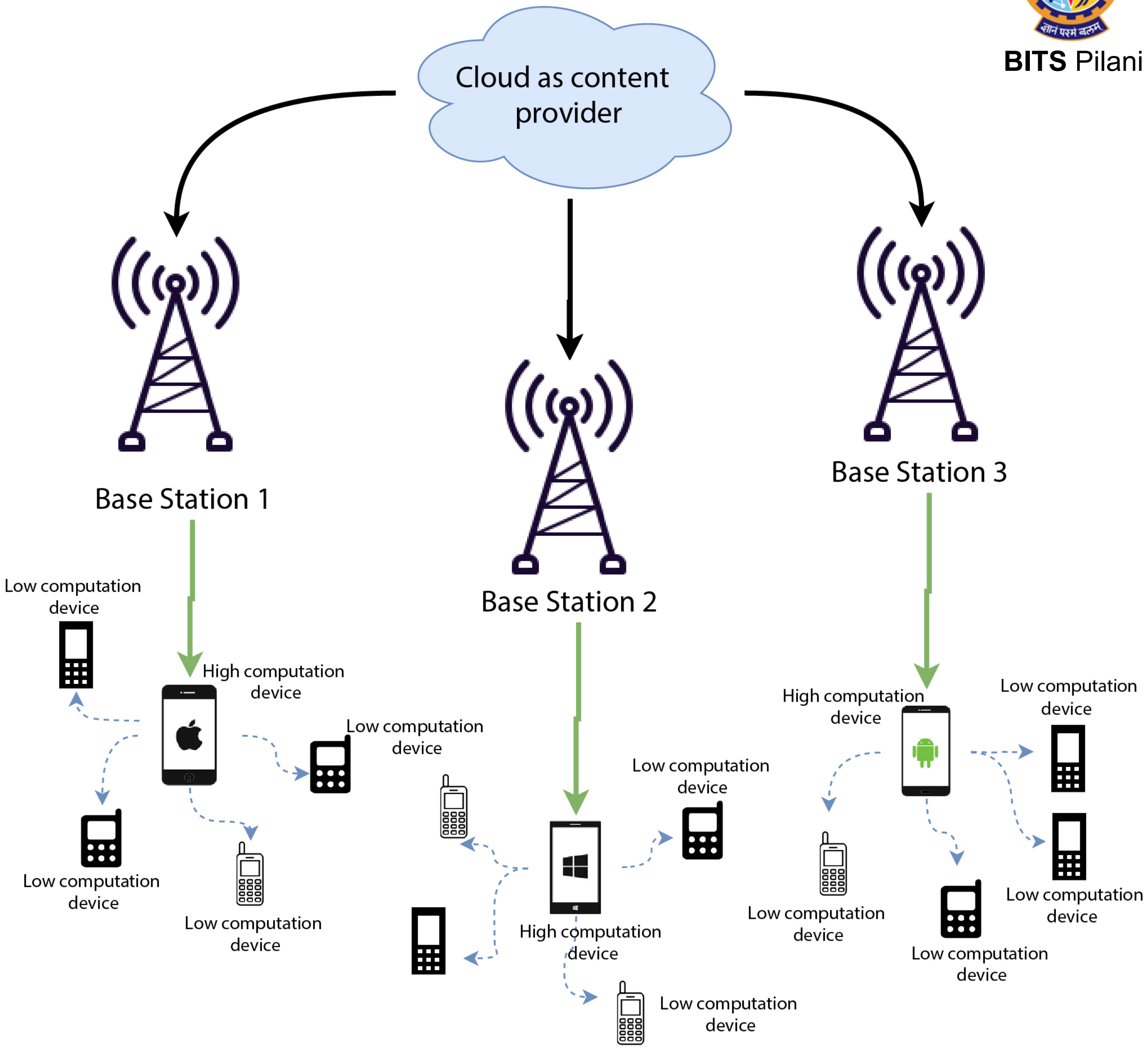
Introduction

Mobile Data Offloading
The use of complementary network technologies for delivering data originally targeted for cellular networks.

Benefits:

- reduces operational costs
- reduces the congestion on the cellular networks, thereby freeing up bandwidth
- improves the Quality of Service (QoS) delivered to the end-user



Existing Solutions for Mobile Data Offloading

- Prediction-Based Mobile Data Offloading in Mobile Cloud Computing (Dongqing Liu et al.)
- Computation Offloading With Data Caching Enhancement for Mobile Edge Computing (Shuai Yu et al.)
- An Incentive Framework for Mobile Data Offloading Market Under Price Competition (Hamed Shah-Mansouri et al.)
- A Blockchain-Based Offloading Approach in Fog Computing Environment (Wenda Tang et al.)
- Pricing Mobile Data Offloading: A Distributed Market Framework (Kehao Wang et al.)

Drawbacks of existing centralized approaches

Mobile offloading solutions that leverage centralized architectures are constrained by various limitations:

- The centralized architectures act as host to several kinds of smart attacks.
- Such architectures are often associated with extensive infrastructure requirement.
- They lack mechanisms to motivate the users to engage themselves in the network pro-actively.

Drawbacks of existing blockchain-based approaches

- Generic blockchain-based systems might fail in scenarios of deadline-sensitive offloading task owing to the high power consumption required in the mining process.
- The offloading tasks often include micro-transactions between the service providers and users, which are much less than a blockchain miner's incentive to add a block in the chain.
- The forking and pruning process in normal blockchain reduces the efficiency of work done by the network nodes.
- Over and above, the traditional blockchain algorithm does not consider the time-stamp ordering of the transaction entry while processing them.

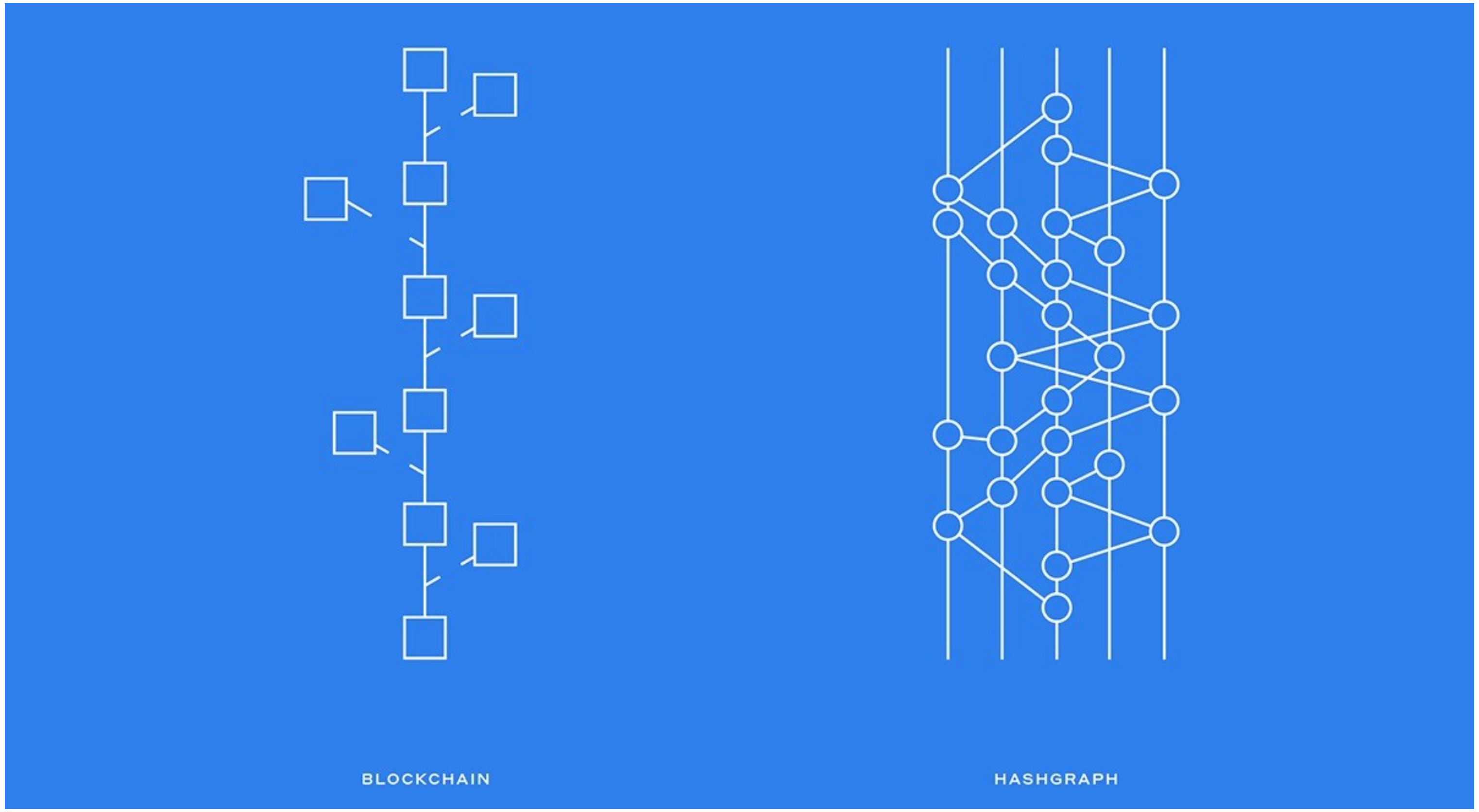
Our Contributions

Although there have been various recent attempts to perform mobile data and computation offloading tasks, there is no peer-to-peer, secure, and cost-optimal framework existing for the same.

- To this end, we propose a DAG-based peer-to-peer network of mobile users where users can securely enter or leave the network and can perform data and computation offloading tasks.
- A Hashgraph consensus algorithm is used to schedule the offloading tasks based on the least deadline time for computation.
- A game-theoretic model is presented to negotiate and choose the best mobile device with high computation power to compute tasks of mobile devices with low computation power in a cost and time-optimal way.

What is a Tangle?

Hashgraph, based on the concept of Directed Acyclic Graph (DAG), is the data structure behind Hedera's distributed ledger and protocol. Hashgraph adopts some elements from the traditional blockchain and realizes some entirely new ones that allow it to overcome the limitations of traditional blockchain.



CATEGORY	BLOCKCHAIN	HASHGRAPH (DAG)
DATA STRUCTURE	Data structured in blocks in order of transactions which are validated by miners in the ecosystem.	In the Hashgraph data is stored in the form of events that consist of a set of transactions, the event's parents, a timestamp, and a signature from the node that created an event.
CONSENSUS	Participants have the ability to mint new tokens via different consensus algorithms.	Nodes create consensus through virtual voting.
TRANSACTIONS PER SECOND (TPS)	Highly limited in terms of scalability and TPS.	A unique consensus mechanism reduces computational burden hence high scalability and TPS.
VALIDATION OF TRANSACTIONS	Miners have the power to postpone a transaction or cancel it entirely.	Virtual voting and Gossip about Gossip protocol ensures that transactions are validated by the majority.

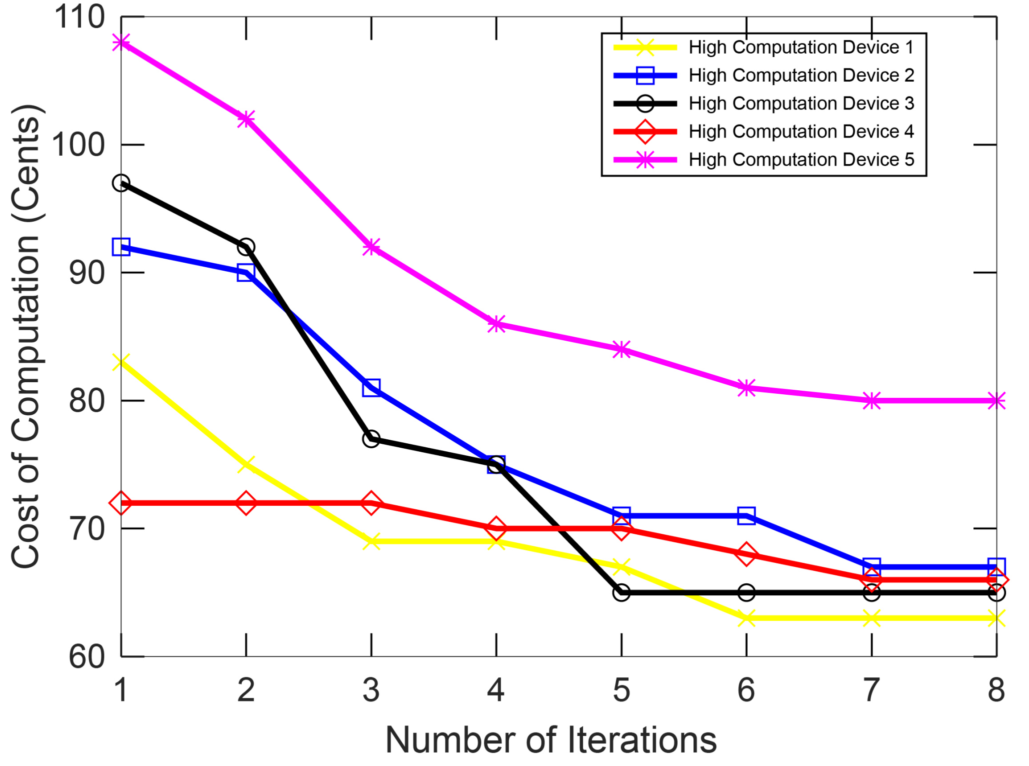
Proposed Model

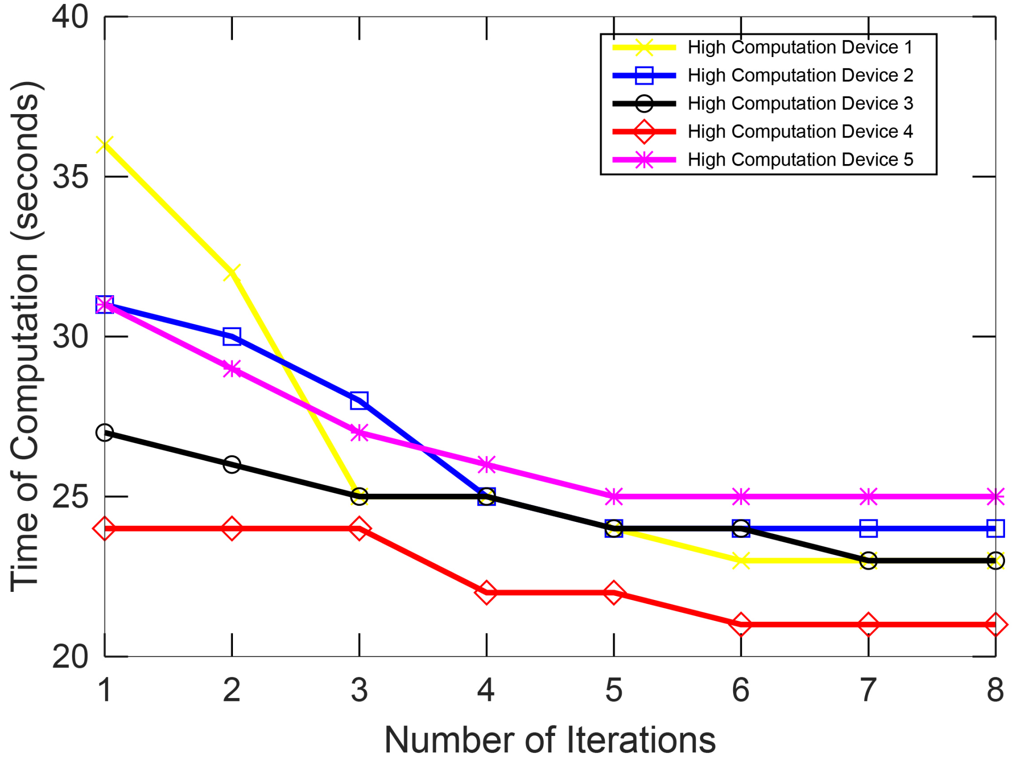
- In this work, a Hashgraph based distributed network of mobile users is created for distributed mobile data offloading.
- The low computation mobile devices can submit a request to high computation mobile devices in the form of a transaction on the DAG.
- The gossip protocol is then used to forward the need and state of each device in the network. The transaction is differentiated with a flag that is set to ’1’ if the node wants to offload a task and ’0’ otherwise. Hashgraph shares events or transactions to other nodes in the network through rounds.
- Following this, a virtual voting algorithm ensures that consensus is achieved in the network. In the virtual voting mechanism, although all the nodes calculate their votes separately, still, because they have the same consistent copy of DAG, all the votes are calculated as same, resulting in a 100% byzantine agreement.

- Next, all the events created in the network are ordered. The consensus time-stamp of a transaction is calculated using the median of the time-stamp at which the nodes received that particular transaction. This is done for all the events in the DAG, post which the events are put in order for performing offloading tasks.
- Post this, a suitable price for offloading the task is determined using an iterative auctioning process.

Consider a low computation device that wants to compute a task requiring multiple operations for which the data requirement is in the range of [120, 200] kilobytes (KBs). The offloading cost over the cellular network is assumed to be 3 dollars while the cost associated with task offloading over the WiFi network is assumed to be 70 cents. We consider 5 high computation devices as participants in our game-theoretical model. We assume that the cost given by the low computation device is in the range of [60, 110] cents, while the specified time is considered to be in the range of [20, 40] seconds. The values of cost parameter (C_c) and time parameter (C_t) are taken to be 0.6 and 0.4 respectively.

Results





The variation in the time and cost values offered by the high computation devices to win the task offloaded by a low computation device is shown in the figures above. For each iteration, the device with the least objective value Ω (a metric that takes into account both time and cost) is announced as the winner. It can be observed that the high computation device that wins the offloading task does not update its cost and time values in the subsequent iteration.

Figure 2(a) shows the objective values of each high computation device after each iteration. The device with the least objective value (Ω) is announced as the winner for that iteration. Figure 2(b) shows the cumulative win count of all the high computation devices after each iteration. It can be seen from the graph that once the stopping condition is achieved, high computation device 1 has the highest win count and therefore wins the mobile offloading task.

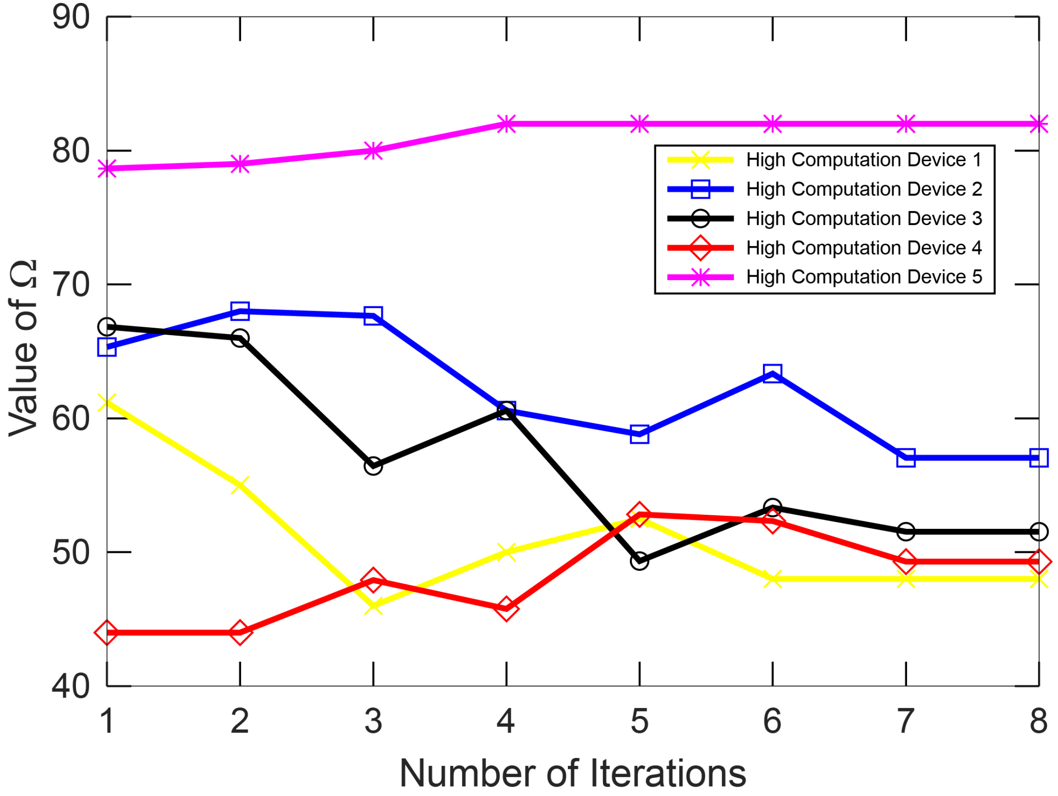


Figure 2(a)

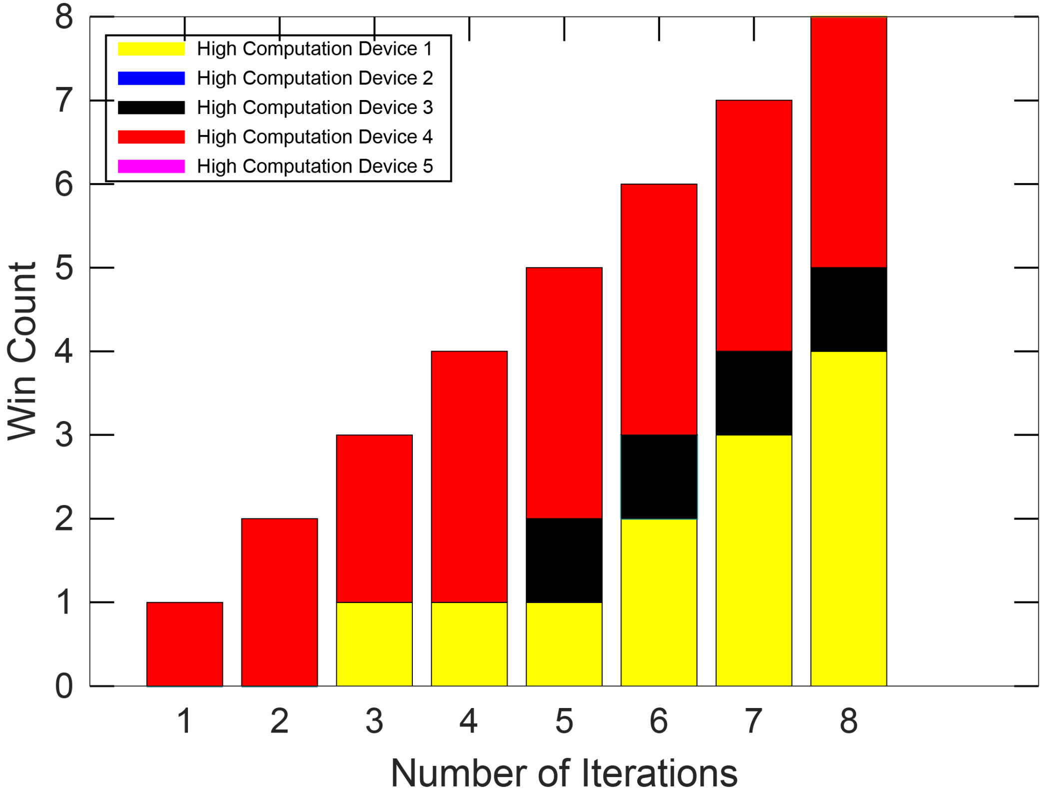


Figure 2(b)

Conclusion

- We propose a secure data offloading strategy based on the Hashgraph consensus mechanism that takes into consideration the deadline constraint.

- A peer-to-peer network of mobile users is created in which the users may either choose to offload their tasks to other high computation devices or may choose to perform the computation task on behalf of other low computation devices.

- A game-theoretic bargaining model has also been implemented to ensure task computation in a cost optimal and time-efficient manner. The results obtained confirm the effectiveness of the proposed offloading model.

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Thank you